SWEET POTATO PRODUCTION IN UGANDA IN A CHANGING CLIMATE: WHAT IS THE ROLE FOR FERTILISERS?

This policy brief for the Ugandan Government covers the use of manure and inorganic fertilisers in sweet potato production, including how fertiliser use in sweet potato production can contribute to boosting yields, livelihood resilience, improving diets and fighting malnutrition in Uganda in the face of climate change.

EXECUTIVE SUMMARY

- Sweet potatoes are an important crop in Uganda for food security and combatting Vitamin A deficiency.
- Current use of fertilisers for sweet potato production in Uganda is low.
- Encouraging increased use of fertilisers may boost yields of sweet potato, helping to build livelihoods resilience to climate impacts, support food security and improve diets.
- Fertilisers are most effective when used as part of an integrated soil and crop management plan, including rotational cropping, intercropping and combined use of manure and inorganic fertiliser.
- Farmers should be supported to develop integrated soil and crop management plans. Farming knowledge and information can be effectively shared through participatory local radio programmes, as demonstrated by previous projects run by the Walker Institute in Uganda, Ghana and Burkina Faso.
- Farmer investment in fertiliser use could also be supported by policies to develop a strong market demand and supply chain for sweet potato products, which would increase market value of the crop and the return on their investment.

Figure 1: Sweet Potato farmers in Mukono, Uganda. © Walker Institute 2020

INTRODUCTION

Sweet potato is one of the most widely grown root crops in sub-Saharan Africa (SSA). In Uganda, it is an important crop, for rural smallholder farmers in particular, as it has significant potential to improve their food security. It has the benefits of producing a crop after 3 to 5 months, the possibility for piecemeal harvest, reliable yields in sub-optimal growing conditions, and lower labour input requirement than other staple crops[1]. Furthermore, orange-fleshed sweet potatoes have high β-carotene content and therefore potential to combat vitamin A deficiency, a major health issue in SSA[2–4].

However, sweet potato yields on smallholder farms remain low compared to their potential[5]. One of the key constraints on the productivity of sub-Saharan African farming systems is the poor nutrient content of the soils. In Uganda, soil nutrients are declining faster than anywhere else in the world[6,7]. This is due to soil erosion, leaching in heavy rains and the over-cultivation of plots[8]. Integrating fertiliser use into sweet potato production systems therefore has the potential to boost yields of sweet potato and contribute to improving food security, health, and livelihoods resilience in the face of climate change. This policy briefing covers the possible impacts of climate change on sweet potato production, impacts of soil fertility and fertiliser use on sweet potato production, opportunities for supporting farmers to increase soil fertility, and recommendations for policy and practice.

IMPACTS OF CLIMATE CHANGE ON SWEET POTATO PRODUCTION IN UGANDA

Climate change is projected to continue the current warming trend in Africa, with annual mean temperatures likely to increase beyond 2 degrees above pre-industrial temperatures by the mid-21st century under a high greenhouse gas (GHG) emissions scenario[9]. How the climate will change in Uganda over the coming decades however, remains uncertain. Under the "Future Climate for Africa" HyCRISTAL project, this uncertainty was captured in the in a set of stories that describe three possible futures for rural East Africa in 2050[10]. These futures do not cover every possible outcome projected but seek to describe some of the resulting impacts that could be experienced in rural areas. However, these impacts will vary across the region due to a range of local factors. Moreover, there has been relatively little research into the how these will affect sweet potato production compared to other staple crops such as maize and wheat.

Sweet potato is perceived to be a drought-resilient crop, particularly compared to other staple crops[11,12], and varieties resistant to drought, along with pests and disease, are continuously being developed in Uganda[13,14]. Modelling sweet potato under climate change indicates that sweet potato production may increase in East Africa, as increasing temperature and rainfall could increase yields[15]. Similar increases in yields under climate change have been predicted in other parts of the world, including for example, Jamaica[16]. Although increasing atmospheric CO_2 concentrations may be a factor in increasing yields, any potential improvements will be limited by nutrient and water availability[17,18]. There may also be negative impacts on sweet potato production through climate change, for example enhanced dispersal and activity of pests– including weevils[19], sweet potato butterfly and whiteflies[20], and diseases– notably *Alternaria* fungal blight[21].

In the Sweet Potato Catalyst Project[22], we are working to further characterise the impacts of climate change on sweet potato yields in Uganda. We are combining information about how yields are likely to be affected by climate change both directly (e.g. from changing rainfall patterns) and indirectly (e.g. through rising temperatures affecting pest distributions), using storylines to describe possible futures[2]

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IMPACTS OF SOIL FERTILITY AND FERTILISER USE ON SWEET POTATO PRODUCTION

In Uganda, smallholder farmers typically achieve only half the sweet potato tuber yields of on-farm trials[13]. Yields are similarly low in other sub-Saharan African (SSA) countries. For example in Malawi farmers typically reach around 30% of potential yields[24]. This yield gap is caused by a number of factors, including soil fertility. It is estimated that improving agronomic practices, including nutrient management as well as planting techniques and spacing, could increase sweet potato yields in sub-Saharan Africa by 60%, but this could be over 100% if farmers have good access to fertilisers[25].

Box 1: Recommended rates of fertiliser application in sub-Saharan Africa[26]

NPK	6:9:15, 560-1120 kg/ha
Nitrogen (N)	34-45 kg/ha
Phosphorus (P_2O_2)	50-101 kg/ha
Potassium (K_2O)	84-169 kg/ha
Farmyard manure	5 tons/ha

Sweet potato crops can grow with relatively low inputs but require potassium and nitrogen for good development of the roots. With low soil nutrient levels yields are likely to be poor, so organic and inorganic fertilisers can be used. However, if nitrogen levels are too high, the vines of the plants can grow abundantly at the expense of the roots[26]. There has been little research into the effects of fertiliser on sweet potato yields specifically in Uganda, but there have been studies in other countries in Africa and globally. This has been drawn on in the section below.

Organic and Inorganic fertiliser

The effects of fertiliser use can be highly variable. Effects depend on a number of factors, including the crop variety[27–29], local characteristics such as soil type and nutrients[30] and timing of the application[26]. Selection and development of sweet potato varieties should consider how responsive they are to soil fertility as well as disease- and drought-tolerance, There are different guidelines for applying fertiliser to sweet potato planted on mounds compared to ridges[26,31,32], and in Ghana fertiliser had greater effects on plants grown on ridges compared to mounds[33]. The climate can also affect fertiliser impacts, particularly when there is drought[34].

Rates of organic and inorganic fertiliser recommended for use in sub-Saharan Africa are shown in Box 1. Organic fertiliser in the form of manure has been shown to increase sweet potato yields in Brazil[35], Tanzania[36] and Ethiopia[1], however high levels of manure decreased yields in Swaziland[37], which may be due to manure increasing the growth of the vines[33] at the expense of the roots (as noted above). Manure is recommended to be applied a few weeks before planting to give it time to begin to decompose in order to avoid introducing weeds[26]. Inorganic NPK (nitrogen, phosphorus, potassium) fertiliser has had positive impacts on tuber yields in Tanzania[36,38], but did not affect yield in a study in Kenya[39]. Application of nitrogen fertiliser increased root yield in the US[28], Nigeria[30], and Papua New Guinea[40], but another study in Nigeria found no influence on root yield[41]. Potassium fertiliser can also improve yields (e.g. in Nigeria[29,42] and Egypt[43,44]), with rates depending on the country[45], but does not always have an effect (e.g. in Ethiopia[1]). Inorganic fertiliser may also have other benefits such as reducing weight loss and rotting post-harvest[27], and increasing the β-carotene content of some varieties[46–48]. Synthesis of all published study results from Africa in the Evidence for Resilient Agriculture database showed an overall positive effect of both organic and inorganic fertilisers on sweet potato yield (Fig. 1), comparable to the yield gain on maize.

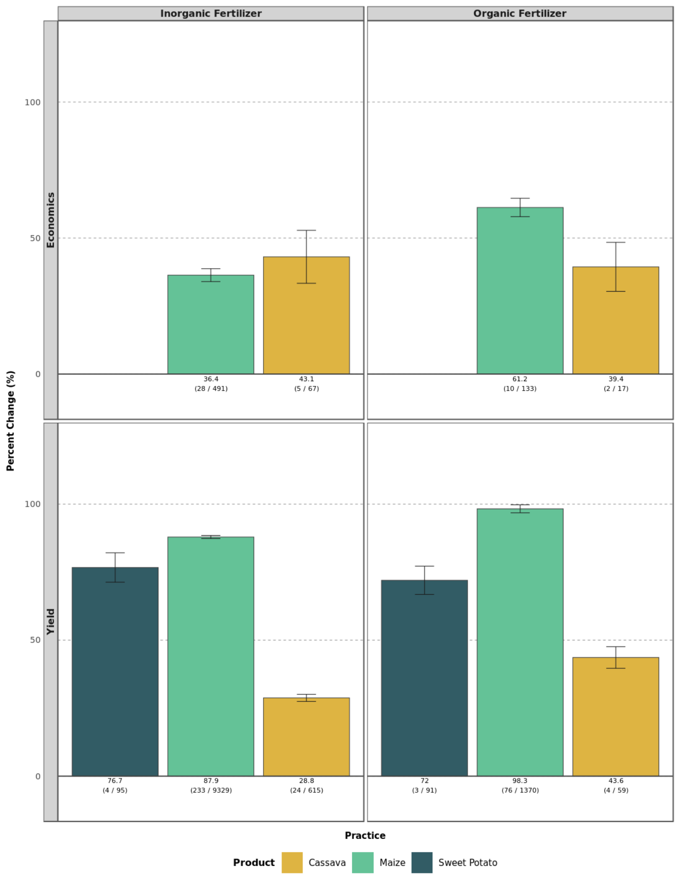

Figure 1: Impact of inorganic (left panel) and organic (right panel) fertiliser use on % change in economics (top panel) and yield (bottom panel) for three crops: sweet potato (blue), maize (green) and cassava (yellow). % change in economics includes changes to cost, economic performance and income. Further details on data synthesis is available from the CGIAR CCAFS Evidence for Resilient Agriculture (ERA) database. Graphics produced by the ERA web app (https://era.ccafs.cgiar.org/analysis/).

In some cases, using combinations of organic and inorganic fertiliser can lead to better sweet potato yields than just using one type alone. Combinations of chicken or cow manure and inorganic fertiliser produced better yields than either individually in Ghana[33], Nigeria[49,50], Ethiopia[1] and Papua New Guinea[51]. Using inorganic fertiliser with bio-fertilisers improved yields compared to separate application in Uganda and Egypt[5,52].

Fertiliser can also be intentionally applied to increase the quantity and quality of vines produced as planting material. In Uganda, using NPK fertilizer doubled the number of vine cuttings produced[53], and in Tanzania manure applied either alone or with NPK increased vine production[54]. Further work is required to establish the optimum fertilizer application for this purpose[55].

Integrated soil and crop management

There may be benefits to intercropping or sequentially cropping sweet potato with maize or other crops with low potassium requirements[56], as sweet potato requires higher levels of potassium than maize, but less nitrogen and phosphorus[26]. This practice has the added advantage that sweet potato will benefit from any fertiliser applied to the other crop[31]. However, results from Ethiopia suggest sweet potatoes need full sunlight, so intercropping with maize or sorghum is only suitable with erect leaved varieties, relay or sequential cropping[1]. Recycling healthy sweet potato vines back to the soil after harvest may also reduce the loss of nutrients in a plot, including potassium[57].

Sweet potato yields can also be improved by planting after nitrogen-fixing legumes, which transfer nitrogen from the atmosphere to the soil. In trials this has increased yield more than the application of NPK fertiliser[26]. This is likely due to the previous crop also providing additional nutrients and improving the soil structure[26]. Soil structural properties can be as important for getting regular good-sized roots as the chemical properties of the soil[32]. In Nigeria, conventional tillage increased tuber yields by 30% compared to zero tillage[49].

SUPPORTING SWEET POTATO FARMERS TO IMPROVE SOIL FERTILITY

The majority of sweet potato farmers in Uganda are smallholders, producing for household consumption and local markets[58]. Increasing the productivity of sweet potato production through fertilization, and integrated soil and crop management has the potential to improve household food security, nutrition, income, and livelihood resilience to climate impacts.

Benefits to farmers of increasing sweet potato yields

Increased household consumption of orange-fleshed sweet potato can have significant health benefits. It can provide additional calories to combat undernutrition, particularly for poorer households who typically obtain over 60% of their energy needs from food staples including sweet potato[58]. Orange-fleshed sweet potato (OFSP) also contains high concentrations of β-carotene, which the body converts into vitamin A. In 2016 in Uganda, 9% of children aged 6-59 months were found to suffer from vitamin A deficiency[59], which can lead to increased risk of child mortality, blindness and anemia[3]. Introduction of OFSP into diets in Uganda and elsewhere has been shown to increase vitamin A intake[2–4].

With increased sweet potato yields there may be increased opportunities for sale at market. This additional income can support livelihood resilience in multiple ways. For example, by providing income to invest in farm improvements or assets such as livestock, money for school fees and other expenses, or options to diversify the household diet. Building livelihood resilience is essential to ensuring vulnerable households and communities are better able to cope with the impacts of climate change[60]. However, significantly increasing sales of sweet potato would require development of the full value chain, including diversification of uses and products made from sweet potato[61].

Options for improving soil fertility

Analyses of the economics of fertiliser use for sweet potato production in Africa are severely lacking (Fig. 1). However, expert knowledge suggests that a key barrier to increased use of fertiliser on sweet potato in Uganda is the current low market value of the crop combined with high farm-level fertiliser prices[58], which are among the most expensive in the world[6]. Access to organic fertiliser, or training to prepare and use it, is also lacking[58]. Investment in improving soil fertility is therefore not considered cost-effective[58]. Similarly in Ghana, the cost of inorganic fertiliser and declining soil fertility are among the top production constraints on sweet potato identified by farmers[61]. Entry points for policy interventions to increase fertiliser use could focus on the disparity between the low market value of the crop and high cost of inorganic fertiliser. Options for intervention could include supporting the development of the sweet potato value chain[61], increasing access to farmer credit[62] and investment in infrastructure to reduce fertiliser costs[63].

At the farm level, one option for combatting the high cost of inorganic fertilisers is to increase the efficiency of on-farm nutrient management by including the use of fertiliser within integrated soil and crop management practices. Depending on the site-specific context, an integrated strategy could combine inorganic fertiliser use with organic matter (such as manure), water harvesting, measures to control soil erosion and rotational cropping practices[62–64]. Manure is likely to be more readily available in many parts of sub-Saharan Africa than inorganic fertiliser[26], particularly as it is cheaper and locally produced. A key benefit to rotational cropping practices is that investment in soil fertility for higher market value crops, such as maize, provides additional returns by increasing sweet potato yield[58]. Rotational cropping with legumes, which fix nitrogen in the soil, is an effective low-cost alternative to fertiliser application. Capacity building of farmers in developing site-specific, integrated fertiliser management strategies will be critical in supporting them to build soil fertility and boost yields of sweet potato. Local radio programmes organised in collaboration with farmers, extension officers and experts can be a successful knowledge exchange tool for communicating farming knowledge, with listening groups and interactive phone-ins to build community engagement[65]. This approach has been used by the BRAVE project[66], run by the Walker Institute in Ghana and Burkina Faso, where 83% of callers reported that they made changes to farming or livestock activities because of information they heard on the radio programmes organised by the project.

RECOMMENDATIONS

- Sweet potato fertiliser requirements are context-specific and depend on the crop variety and local conditions such as the soil characteristics and climate. On-farm trials in each agro-ecological zone in Uganda are needed to determine optimum fertiliser application to benefit yield, both for tubers for consumption and vines for use as planting material.
- Given the current low market value of sweet potato, investment in soil fertility improvements may only be financially viable in an integrated soil and crop management system. This includes rotational cropping, whereby fertilisers used for other higher-value crops will provide residual benefits to the sweet potato and rotational cropping with legumes to provide additional nitrogen.
- Farmers should be supported to develop integrated soil and crop management plans to improve household food security, nutrition, income, and livelihood resilience to climate impacts. Farming knowledge and information can be effectively shared through participatory local radio programmes.
- Farmer investment in fertiliser use could also be supported by policies to develop a strong supply chain for sweet potato products, which would increase the market value of the crop.

RECOMMENDATIONS FOR POLICY AND PRACTICE

We are working with Climate Action Network - Uganda (CAN-U) to share information generated by the project with relevant stakeholders in Uganda. CAN-U are training community farmer champions in Mukono, Uganda in the production of sweet potato and in policy influencing. CAN-U are also leading advocacy efforts, ensuring the work addresses the decisions being taken by policymakers and research findings and feeds in appropriately to policymaking at a national level on the Koronivia Joint Work on Agriculture[1] (KJWA). The KJWA within the United Nations Framework Convention on Climate Change (UNFCCC) emphasizes the importance of agriculture and food security in the climate change agenda. By mainstreaming agriculture into the UNFCCC processes, the KJWA can drive transformation in CAN-U are also leading advocacy efforts, ensuring the work addresses the decisions being taken by policymakers and research findings and feeds in appropriately to policymaking at a national level on the Koronivia Joint Work on Agriculture[2].

The productivity of sub-Saharan African farming systems is often constrained by the nutrient content of the soils. In Uganda, soil nutrients are declining faster than anywhere else in the world[6,7]. However, fertiliser application rates in Uganda remain low[6,7,67]. Inorganic fertiliser was only applied to 2.8% of cropland in Uganda in 2013, mainly concentrated on cash crops such as banana and sugarcane[67]. Very little data exists on fertiliser use in sweet potato production in sub-Saharan Africa, but experts estimate it is uncommon[58]. One study conducted across six districts of Uganda, surveying 192 households, found that only 5.8% and 7.5% respectively of male- and female-headed households applied fertiliser to sweet potato fields[68].

While fertiliser application could have positive impacts on sweet potato production in Uganda, there are challenges to increasing its use, particularly around the high cost of fertiliser compared to the low market value of the crop. Other limitations on the use of fertiliser more generally in Uganda include lack of technical advice for farmers, low access to credit and long distances from markets[7]. Strategies to overcome these challenges may require a gendered approach, with different policies to incentivise fertiliser adoption depending on whether households are male or female headed[69].

Over use of fertilisers can lead to eutrophication and pollution of water ways[64] and emissions of nitrous oxides, which are potent greenhouse gases (GHGs)[70]. However, soil fertility is so low in Africa, and use of fertilisers so low, that overapplication and pollution is unlikely to be an environmental issue. In fact, it has been argued that not to encourage use of fertilisers in Africa would do more environmental damage, as low soil fertility reduces productivity of farms and encourages conversion of forests and other ecosystems into agricultural land[62,63,71]. Supporting integrated soil and crop management practices, such as rotational cropping with legumes, may be the most cost-effective and environmentally-sound option to support robust sweet potato yield by building soil fertility.

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